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Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Executive summary



Practical experience with a novel Dutch approach for the qualification of military flight simulators



Introduction

Since 2005 the Netherlands has an independent Military Aviation Authority (MAA-NLD) to enhance safe operation of military aviation.

The MAA was confronted with several challenges when it started to develop standards and regulations for simulators. Where the military has operations similar to civilian operators, civilian rules are quite appropriate. But military operation can differ considerably from civilian operations and can lead to different and additional regulations. Secondly, existing simulators were not always built against a known standard, so the MAA also has to

qualify simulators which possess a very limited data set.

In this paper we explain the qualification system as designed for the MAA and inform you about the first experiences with the Dutch system.

Considerations

It is impracticable to set Flight Simulator Training Devices (FSTD) standards in absolute terms. The FSTD is not a goal in itself but training in an FSTD is an integral part of the complete training syllabus. Consequently it is better to build a direct relation between simulator capabilities and the

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required training impact. This implies that the Military Aviation Authority of the Netherlands (MAA-NLD) will not demand the operator to have a simulator with a certain standard. However having a certain standard of simulator will enable the operator to economize on actual training hours.

An FSTD can have the following impacts on a specific task:

- The FSTD can fully replace actual flying for this task. (including 'ab initio' pilots).
- The FSTD is good enough to replace a certain percentage of actual flying for this task.
- The FSTD is not suited to train for this task.

The MAA has designed a system to rate all the major FSTD features (sixteen in total). The number of levels per feature range between two and seven.

The method employed is based on the following principles:

- Do not rate the complete simulator but qualify subsystems (features);
- Rate the training tasks vs. subsystem qualification level. These tasks include specific military operations as well.

This gives the operator the possibility to exploit all the capabilities. Furthermore it is easy for the operator to check which FSTD upgrades will be economical.

Results and conclusions

The initial regulation for aircraft (both fixed wing and rotary wing) simulators (MAR-FSTD) is drafted. Based on this version of the MAR-FSTD the qualification of Dutch military simulators has been started. The aim is to give the operator maximum flexibility in the employment of existing and future simulators.

An interesting point for existing simulators is 'how to handle when no proof-of-match data with the real aircraft are available' and how to get to an alternative Qualification Test Guide (QTG). Results of some qualifications will be presented.

We could benefit a lot from the existing JAA regulations, and we could even combine the helicopter and fixed wing regulations and use the best of both worlds. We were able to use a similar methodology for military sensors, threats and targets as is used in ICAO 9625. ("Manual of Criteria for the Qualification of FSTDs)

However, the existing MAR-FSTD is still a document under construction and we are refining it, based on the initial experiences we have. It is also rewarding to see that the operator is welcoming this regulation as a way to improve its training, improve the quality of its simulators and to guide him in making investment decisions.



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Practical experience with a novel Dutch approach for the qualification of military flight simulators

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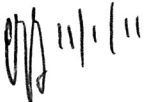

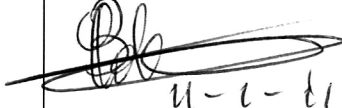
¹ Militaire Luchtvaart Autoriteit

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Summary

The initial regulation for aircraft (both fixed wing and rotary wing) simulators (MAR-FSTD) is drafted. Based on this version of the MAR-FSTD the qualification of Dutch military simulators has been started. The aim is to give the operator maximum flexibility in the employment of existing and future simulators.

The method employed is based on the following principles:

- Do not rate the complete simulator but qualify subsystems;
- Rate the training tasks vs. subsystem qualification level. These tasks include specific military operations as well.

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Abbreviations

FSTD	=	Flight Simulation Training Device
FSTD OE	=	FSTD Organization Exposition
ICAO	=	International Civil Aviation Organization
JAA	=	Joint Aviation Authorities
MAA (-NLD)	=	Military Aviation Authority The Netherlands
MAR	=	Military Aviation Requirement
MLA	=	Militaire Luchtvaart Autoriteit; see MAA
POM	=	Proof-of-Match
QTG	=	Qualification Test Guide

1 Introduction

Governments have a long tradition in establishing national and multinational agencies to control private enterprises especially those involved in potential hazardous operations. ICAO, JAA, EASA and others are good examples. But traditionally governments have been less keen to operate agencies to check it self. Military aviation, being a governmental organization did not have an independent Military Aviation Authority to enhance safe operation. However, since 2005 the Netherlands has an independent Military Aviation Authority (MAA-NLD).

The MAA-NLD was confronted with several challenges when we had to develop standards and regulations for simulators. Where we have operations similar to civilian operators, civilian rules are quite appropriate. But military operation can differ considerably from civilian operations and can lead to different and additional regulations. Secondly, existing simulators were not always built against a known standard, so we also have to qualify simulators which possess a very limited data set.

In this paper we explain the qualification system we have designed and inform you about our first experiences with the Dutch system.

2 Considerations

It is impracticable to set Flight Simulator Training Devices (FSTD) standards in absolute terms. The FSTD is not a goal in itself but training in an FSTD is an integral part of the complete training syllabus. Consequently it is better to build a direct relation between simulator capabilities and the required training impact. This implies that the Military Aviation Authority of the Netherlands (MAA-NLD) will not demand the operator to have a simulator with a certain standard. But having a certain standard of simulator will enable the operator to economize on actual training hours. An FSTD can have the following impacts on a specific task:

1. The FSTD can fully replace actual flying for this task.
(Even for 'ab initio' pilots).
2. The FSTD is good enough to replace a certain percentage of actual flying for this task.
3. The FSTD is not suited to train for this task.

To implement this system, it is necessary to qualify simulators and tasks to enable quick checking which task can be performed with a certain FSTD. The MAA has designed a system to

rate all the major FSTD features (sixteen in total). The number of levels per feature range between two and seven.

This rating of simulation features is comparable with the latest ICAO document 9625 [3rd edition] “Manual of Criteria for the Qualification of FSTDs –Aeroplanes”.

The MAA-NLD however is not combining these rating in one overall rating, but keeps a finer grid where all features can be recognized. This gives a finer resolution to range each FSTD and gives the operator the possibility to exploit all the capabilities. Furthermore it is easy for the operator to check which FSTD upgrades will be economical.

2.1 Features (or subsystems)

The different features identified are:

1. Hardware:
 - a. Instructor / Operator Station (IOS)
 - b. Visual, (image and Field of View)
 - c. Motion (envelope and phase)
 - d. Sound
 - e. Cockpit
2. Standard software models
 - a. Aircraft performance and control
 - b. Aircraft subsystems (including weapon system(s))
 - c. Avionics performance
 - d. Military sensors performance
 - e. Weather
 - f. ATC (includes: navigation database and ATC communication).
3. Mission related software models (specific military requirements)
 - a. Threats, targets, weapon trajectories and effects, ECCM and ECM, hoisting, sling load, aerial deliveries.
 - b. Cooperative system modelling. (Tankers, formation members, moving landing platforms etc.).
4. System integration and correlation

Each feature is rated and given a level. For the determination of levels analogy has been sought with the JAR rating system. And for each feature a cross reference is made with applicable JAR standard. For example, the Joint Aviation Requirements JAR-FSTD A distinguishes 4 levels of full flight simulators and for each level the requirement for the motion is different. This will also give at least four levels of motion in the Military Aviation Requirement MAR-FSTD.

However, if for the four levels of simulator in the JAR only two different engine models are described, the MAR FSTD will only have two types of engine models.

The qualification of a simulator is done by the MAA. The rating of the FSTD will be based on an inspection of the hardware, software, documentation and on tests performed. The test will be performed by a qualified inspection team. The operator will be given a qualification certificate which states the level of his FSTD. (e.g. 16 times a level for each feature)

2.2 Training credits

The required training per type of operation is described in the MAR-OPS and the approved Operating Manual of the operator.

If the FSTD has the maximum required level for a particular task the operator is allowed to use the FSTD for the following percentage of training:

- 100% of the initial training
- 100% of the re-currency training
- 100% of the currency training
- 100% of the proficiency checks including upgrade testing.

If the FSTD has the minimum required level for a particular task the following percentage of training for that task may be performed in the FSTD:

- 50% of the initial training
- 50% of the re-currency training
- 50% of the currency training
- It may be used for proficiency checks if the previous check was in the aircraft and the test is not an upgrade.

If an FSTD does not fully meet the requirements for a 50% or 100% replacement of training for a certain task, but the deficiency is compensated by other means of training acceptable to the authority, the authority may grant the right to use the FSTD combined with the additional means for the level of task replacement sought.



2.3 MAR FSTD technical requirements per feature

Two examples are given below:

Visual Field-of-View (FOV)

Qualification Level	General Technical Requirements		
1	FOV 45°H x 30°V	per pilot	(=JAR level A)
2	FOV 120°H x 40°V	per crew, continuous	
3	FOV 120°H x 60°V	per crew, continuous	
4	FOV 180°H x 40°V	per crew, continuous	(=JAR A level D)
5	FOV 180°H x 60°V	per crew, continuous	(=JAR H level D)
6	Forward hemisphere 180°H x 90°V up + 45°V down		
7	FOV identical with FOV from the pilot station of the simulated aircraft.		

Military sensors

Qualification Level	General Technical Requirements
1	Generic sensor performance but with correct switchology
2	Representative sensor performance
3	Specific sensor performance (including effects of weather).
+ 0.2	Sensor integrated with other databases (' within' same FSTD)
+ 0.5	Abnormal and failure modes are included.

2.4 Flight tasks to be trained

Interviews with and consultation of experienced instructor pilots and simulator operators have resulted in two sets of training tasks; one for all fixed-wing aircraft and the other for rotary-wing aircraft. The training is divided into relatively high level task descriptions. This keeps the amount of different tasks to a manageable level, but still with enough segmentation to differentiate in real life and thus in the necessary simulator features.

Overview of military fixed-wing flight tasks

Tasks, identical to civil aircraft

Task (general)

Ground operations

Normal flight ops

Malfunctions

Specific military tasks

Abnormal Flight operations

Spins

Departures

Asymmetric Flight (asymmetry caused by engine(s)
wing stores or mechanical failures)

Trainer

Forced Landing

Aerobatics

Fighter-general

Defensive actions

AAR A/A refuelling

NVG operation

IIR operation

Fighter Air to Air

Close in visual air combat (BFM, VID etc)

Medium range visual air combat

Beyond visual range Air to Air

Fighter Air to Surface

Visual Weapon employment

Low level

Visual weapon employment

medium level

Sensor based weapon employment

Close Air Support

Reconnaissance medium level

Reconnaissance low level

Tactical Transport

Non straight-in approach/landing

Mountain operations

Para drop

Aerial cargo delivery

Parachute extraction of cargo

Rough field landing

Stuck cargo on delivery ramp

ECM & evasive manoeuvres

Tanker

air refuelling [delivering]

air refuelling [receiving]

Multi-ship operation

Close formation flying

Tactical Formation Flying

Integrated Operations

Mission rehearsal

Overview of rotary-wing flight tasks

Task
Ground operations
Start up
Taxi
Normal flight ops
Take off
Take off confined area
Climb VMC
Instrument departure
Level flight (medium level navigation IMC)
Level flight (medium level navigation VMC)
Level flight (low level navigation)> 150'
Mountain operations
Hot & high operations
NVG operations
NVS (IIR) operations
Instrument approach
Descent
Quick stop
Hover
Landing IFR(on controlled airfield)
Landing circuits
Landing confined area
Pinnacle landing
Approach & Landing under adverse weather conditions (snow/rain/icing)
Slope landings
Cross wind landings/ windshear
Brown out/ white out landings
Malfunctions
Autorotation
Engine related emergency procedures
System and avionic related emergencies
Landing related emergencies
Flight control emergencies
Rotor & drive train related emergencies
Emergency descent
Unusual attitudes
Sling load emergencies
Military operations
Hoisting
Under slung load operations
Roping, paradrop, abseilen hover jump
Sonar operations
Deck landings
A/G gunnery (= all weapon delivery)
Threat recognition and reaction
Threat manoeuvring
Nap of the earth flying
Multi-ship operation
Integrated Operations
Mission rehearsal

3 Classification of tasks

3.1 Introduction

Humans have sensor capability in the visual, tactile, motion and sound dimension. This capability is limited by the cockpit, which reduces the available field of view, but also the headset will reduce the observed sound levels. The required sensor simulation depends on the specific task to be trained. Some tasks only require a limited number of sensor inputs. (e.g. instrument flying generates less motion and visual cues than BFM). If the simulation of a specific task is within the human sensory resolution the simulation of this task may be considered perfect. Perfect simulation not only requires the hardware to perform accurately but also that the underlying models work with the accuracy required for this task). When simulation is possible within the human sensory limits, the FSTD is capable to replace actual flying. This sets the upper boundary in simulation requirements for this particular task. A checklist for categorizing the maximum level is inserted below.

The lower boundary of a simulation is where the simulator training will still have adequate training value and does not give any negative transfer of training. This lower boundary will be surpassed when time delays exceed certain limits or trends have a different sign compared to reality or simulation differs considerably from reality. However, it is presently not always possible to set absolute criteria for the lower boundary. The checklist for the minimum level gives guidance based on the presently available information. In the end, during the subjective test, the required tasks should be executable without any negative transfer of training in the FSTD and has a positive effect on training of the task.

Even if the simulator hardware and software passes the required maximum level per feature this does not nullify the need to pass the subjective test in which the complete task is evaluated.

3.2 Task qualification checklist for maximum level:

Two examples from the checklist are presented, first military sensors and secondly threats and targets.

An FSTD may have several military sensors (Radar, IIR, AIFF, MAWS etc.) and each sensor shall be rated separately:

- a. If only generic sensor performance with correct switchology is required the minimum is level 1.
- b. If representative sensor performance is required the minimum is level 2.
- c. If specific sensor performance is required the minimum is level 3.
- d. If sensor integration with other databases is required the minimum is level + 0.2.
- e. If normal and abnormal system operation is required the minimum is level + 0.5.

All threats & targets models should be listed. The level is determined per model.

- a. In the ideal case threats and targets are specific (level 3),
- b. However for some tasks the training with a representative threat/target is identical, in the latter case level 2 is sufficient, in the other case level 3 is required.
- c. For 100% flight replacement generic threats and targets are normally insufficient.

It is paramount that the number of different models should be consistent with the level of training sought.

3.3 Task qualification checklist for minimum level:

General guideline: The subjective rating for the minimum levels is primarily done during the initial qualification of the simulators. Therefore all tasks to be flown will be rated by experienced pilots. The primary questions to be answered are:

- a. Do manual skills have to be trained with an exact feel and touch?
- b. Are procedures the same as in the actual aircraft?
- c. Is the workload similar as during the real task execution? When the workload is higher than in the real environment this might be a problem if it leads to a different behaviour. If the workload is considerable lower than in the real aircraft the simulator is probably not fit for the task.
- d. Is the crosscheck similar as in the real environment?
- e. Is crew coordination similar as in the real environment?

Note: All threat and target models should be listed. The level is determined per model. In general, downgrading from specific to representative or from representative to generic is applicable for most tasks.

In the task-feature matrices (one for maximum and one for minimum level requirements) the required qualification level of each feature is indicated for each training task. A part of the rotary-wing requirements are shown below.

FSTD feature	Hardware								Models							
	IOS	Visual		Motion		Sound	Cockpit	Performance & Control	Subsystems	Avionics	Mil. Sensors	Weather	ATC	Threats & targets	Cooperative models	Integration
			FOV		Phase											
Maximum requirements per task (rotary wing aircraft)																
Maximum level	2	3 +0.2 +0.5	7	3 +0.1 +0.2 +0.5	2	3 +0.2 +0.5	5 +5	3 +0.2 +0.5	3 +0.5	3 +0.2 +0.5	3 +0.2 +0.5	3 +0.2 +0.5	4	3	3	3 +0.2 +0.5
FSTD (x)	2		5													
Task																
Military operations																
Hoisting	2	2	5	3.2	2	3	5	4.3	3.5	2	#9	3.2	2	-	3	3
Under slung load operations	2	3	5	3.2	2	3	5	4.3	3.5	2	#9	3.2	2	-	3	3
Roping, paradrop, abseilen hvr jump	2	3	3	3.2	2	3	5	4.3	3.5	2	#9	3.2	2	-	3	3
Sonar operations	1	2	3	3.2	2	3	5	4.3	3.5	3.5	#9	3.2	2	3	-	3.2
Deck landings	2	3	5-6	3.2	2	3.5	5	4.3	3.5	2	#9	3.7	2	-	3	3.2
AVG gunnery (all weapon delivery) #3	2	3	6	3.2	2	3.2	5	4	3.5	3.7	#9	2	2	3	3	3.2
Threat recognition and reaction	2	2	5	3.2	2	3.5	5	3	3.5	3.5	#9	2	2	3	-	3.2
Threat manoeuvring	2	2	6	3.3	2	3.5	5	4	3.5	2.5	#9	2	2	3	-	3
Nap of the earth flying	2	3	6	3.2	2	3	5	4	2	2.7	#9	2.2	2	-	-	3
Multi-ship operation																
Integrated Operations	2	2	5	3.3	2	3.5	5	4.3	3	3.2	#9	3.2	4	3	3	3.2
Mission rehearsal	2	3	6	3.3	2	3.7	5	4.8	3.5	3.7	#9	3.7	4	3	3	3.7
#9. Is specific for the simulator evaluated, final list per aircraft type should include all relevant military sensors																

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4 Practical experience

The practical experience, up to now, can be divided in two parts, first the experience with simulators presently under contract. This involves the NH-90 simulator, the KDC10 simulator and the C-130 simulator, and secondly the experience with existing simulators.

4.1 The new simulators

There were two favourable aspects of the new simulators, first we got involved early in the program and secondly with these simulators there is a lot of commonality with civilian simulators.

The KDC-10 has the least differences. The main difference is the tanker operation which necessitates to model the effect of an aircraft moving into refuelling position and furthermore

the addition of specific tanker scenarios. Fortunately data about the aerodynamic effect of tanker operation were available which makes it possible to incorporate this effect in the flight model and also to verify the correct operation quantitatively. The testing of the scenarios is more a subjective test, the number of players and their behaviour must match the expected behaviour. The basic simulator is built contractual to level D standard¹⁾. We as MAA will translate this to the MAA levels and add levels for the additional features.



The C-130 is a more military aircraft; typical military operations include cargo drop, parachute extraction, rough field landings and flying in a threat rich environment where optimum use has to be made of threat warning equipment, electronic counter measures and manoeuvring. The majority of these military tasks require that the threat and counter measure database is of a high quality and that scenarios are flexible. The most practical way to check the threat is to compare it with the threat database which is maintained by the NLR for the RNLAf. But comparing one database against another is not a sufficient test. On top of that some scenarios will have to be developed where the threat performance can be measured against the pre calculated performance. For instance a manoeuvre which positions the aircraft just outside the lethal zone of the weapon should prevent a hit and inside the lethal zone we should have an opposite effect. It is of course not wise to include detailed requirements for threat and targets in the MAR-FSTD. Classification makes that improper and details about enemy system may change as well. The most important thing the MAA has to establish is the fact of threats are generic, representative or specific.

¹⁾ When the contract was signed the draft MAR FSTD was not yet ready and consequently could not be used.

The NH-90 differs most from civilian systems. This was not only due to the added military sensors with their specific performance but also caused by the operator requirement to be able to simulate deck landings. The latter requirement necessitated a complete different design of the flight loop. Instead of a single disk model a multi element blade model was now required. Furthermore the wind field around the helicopter has to be defined in a much finer grid. This approach will, in theory, enable the NH-90 simulator to be used for deck landing training. The MAA has an additional challenge. We must find a way to validate that the simulated deck landing resembles the actual deck landings. The most convenient way is a Proof of Match (POM) test where actual flight test data is incorporated in the simulator. This in itself is not a problem, however, the actual wind field may differ from the calculated wind field, and the complete wind field is never measured. Therefore we are presently not sure if we can use the same limits as the RAeS reference books are presently using for landing performance.

4.2 Existing simulators

The situation with existing simulators is completely different. Some simulators are bought as part of a military sale, which gave us simulators which were identical to the one the USA had bought. The problem with these simulators is not that they are not up to standard but that we lack the evidence to which standard they perform. A further limitation is that in general these simulators are not capable of automatic QTG testing. This makes it even harder to prove that they maintain a certain standard.

This situation does not look very promising at first sight; however we have some advantages too. We have an experimental test pilot on every type flown. We can use them to gather quantitative data with standard flight test techniques and let them fly similar profiles in the simulator. This approach was also used for the PC-7 simulator. But in that particular case the flight test data was used to tune the flight model from scratch. The experience was that a limited number of dedicated test flights was sufficient to get a good set of data to test the simulator. But there were of course also limitations. These test mostly verified the aircraft behaviour in the air, ground effect and surface effects cannot be collected that easily with simple hand held instrumentation. On the other hand, most of the simulation is not intended to train for those tasks, which makes it a useable method to employ.

The simulator for the Lynx helicopter on the other hand has a relatively high level of fidelity ("D level comparable"). A noticeable limitation exists for military deck landings. The air wake model of the airflow around the ship is generic and the aerodynamic model lacks some details in blade modelling. This level is sufficient for "50 % training", i.e. for training the operational procedures. Final training of the flight handling and qualification of the pilot for this task has to be performed during actual flight, supervised by an instructor.

5 Conclusion

It is a challenging task to develop new regulations. It is of course always nice to do things for the first time. We could benefit a lot from the existing JAA regulations, and we could even combine the helicopter and fixed wing regulations and use the best of both worlds. We were able to use a similar methodology for military sensors, threats and targets as is used in ICAO 9625. However, the existing MAR-FSTD is still a document under construction and we are refining it, based on the initial experiences we have. It is also rewarding to see that the operator is welcoming this regulation as a way to improve its training, improve the quality of its simulators and to guide him in making investment decisions.

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